ADA

DoD COALESCER QUALIFICATION TO MIL-F-52308F AND MIL-F-8901E

INTERIM REPORT
TFLRF NO. 390

by
Gary B. Bessee

U.S. Army TARDEC Fuels and Lubricants Research Facility
Southwest Research Institute® (SwRI®)
San Antonio, Texas

Under contract to
U.S. Army TARDEC
Force Projection Technologies
Warren, Michigan

Contract No. DAAE-07-99-C-L053 (WD44)
SwRI® Project No. 03.03227.44

December 2007

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Approved by:

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U.S. Army TARDEC Fuels and Lubricants Research Facility (SwRI®)

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14. ABSTRACT

Candidate DoD aviation fuel filters were qualified per MIL-F-8901E and MIL-F-52308F. The specifications were revised due to materials no longer being produced. The candidate elements failed the qualification.

15. SUBJECT TERMS Aviation Fuel Filters Jet A JP-8 DoD Fuel Filters

MIL-F-8901E Qualification Testing

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EXECUTIVE SUMMARY

Problems: Additional aviation fuel water separators required qualification. The previous elements were qualified to MIL-F-8901, and some of the materials are no longer produced.

Objective: Perform a qualification of supplied DoD elements per a modified version of MIL-F-8901E and MIL-F-52308F.

Importance of Project: Provide the military of elements in the field to properly filter aviation fuel.

Technical Approach: The technical approach was to modify the canceled test method while incorporating the current test method to include current additives and test contaminants.

Accomplishments: The test articles were evaluated and failed to meet the performance criteria outlined in MIL-F-8901E.

Military Impact: Further qualifications need to be performed using the current product or newer fuel water separators.

FOREWORD/ACKNOWLEDGMENTS

This work was performed by the U.S. Army TARDEC Fuels and Lubricants Research Facility (TFLRF) located at Southwest Research Institute (SwRI), San Antonio, Texas, during the period May 2007 through September 2007 under Contract No. DAAE-07-99-C-L053. The U.S. Army Tank-Automotive RD&E Center (TARDEC), Force Projection Technologies, Warren, Michigan, administered the project. Mr. Luis Villahermosa (AMSRD-TAR-D, MS110) served as the TARDEC contracting officer's technical representative, and Mr. Kenneth Walther (AMSRD-TAR-D/210, MS110), Fuel and Water Support Team, TARDEC, served as the project technical monitor.

The author would like to acknowledge the assistance of Messrs. Raymond Lemes and Max Reinhard, Jr., SwRI, for conducting the filtering testing and Ms. Rebecca Emmot for editing and processing the report.

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1.0 INTRODUCTION AND BACKGROUND

Aviation fuel filters are required for field operations and need to be qualified per military specifications. The current supply of qualified aviation fuel filters is being depleted rapidly with Operation Iraqi Freedom (OIF). Therefore, a new supply of filters needs to be qualified. SwRI was directed to used MIL-F-8901E and MIL-F-52308F test protocols to evaluate the candidate fuel water separators.

2.0 OBJECTIVE AND APPROACH

The objective of this project is to qualify the Army supplied coalescers to MIL-F-52308F and MIL-F-8901E at the Army approved aviation filter test facility at Southwest Research Institute (SwRI), San Antonio, TX.

3.0 TEST FACILITY AND MATERIALS

The SwRI aviation filter test facility has been certified by Vic Hughes (Vic Hughes Associates, Ltd.) and approved by Force Projection Technologies (TARDEC) as an Army approved aviation filter test facility. It is ISO 17025 certified.

Some of the test materials and test analysis required substitution as they are no longer available or are no longer used by the industry. These include:

- HITEC E515 corrosion inhibitor was replaced with HITEC E580, as HITEC E515 is no longer available.

- Shell ASA-3 static dissipater was replaced with Stadis 450, as Shell ASA-3 is no longer available.

- Aqua-glo analysis will be used to determine free water content instead of turbidity, as it is the current industry standard.

- AC Fine test dust was replaced with ISO 12103-1 A2 fine test dust, as AC Fine test dust is no longer available. ISO 12103-1A2 Fine test dust is the industry's equivalent to the old AC Fine test dust.

- The test fuel density and flash point was measured with the test results of 0.8144 kg/L and 56°C, respectively.

4.0 TEST METHODOLOGY

The following sections of MIL-F-8901E were completed for this qualification process:

- Section 4.4.3.6—Differential pressure and media migration (first set of elements)
- Section 4.4.3.7—Red iron oxide
- Section 4.4.3.8—Water removal (second set of elements)
- Section 4.4.3.9—Red iron oxide and water
- Section 4.4.3.10—Inhibited fuel (third set of elements)
- Section 4.4.3.11—Life (fourth set of elements)
- Section 4.4.3.12—Environmental
- Section 4.4.3.13—Storage, high temperature (only sections evaluating the elements)
- Section 4.4.3.14—Storage, low temperature (only sections evaluating the elements)
- Section 4.4.3.15—Resistance to flow (filter-separator elements)
- Section 4.4.3.16—Resistance to salt water (filter-coalescer elements)
- Section 4.4.3.17—Post environmental performance (filter coalescer elements)

5.0 TEST DATA

A summary of the test results for each section is provided below with the data sheets provided in the Appendix.

5.1 Section 4.4.3.6—Differential Pressure and Media Migration (First Set of Elements)

The differential pressure was determined using the first set of elements. Table 1 provides the results for differential pressure as a function of flow rate, with graphical representation provided in Figure 1.

Table 1. Differential Pressure Results

Period	Time, minutes	Percent of rated flow	Differential pressure, psid
1	0 to 10	100	3.3
2	10 to 20	80	2.6
3	20 to 30	60	2
4	30 to 40	40	1.4
5	40 to 50	20	0.8
6	50 to 60	115	3.9

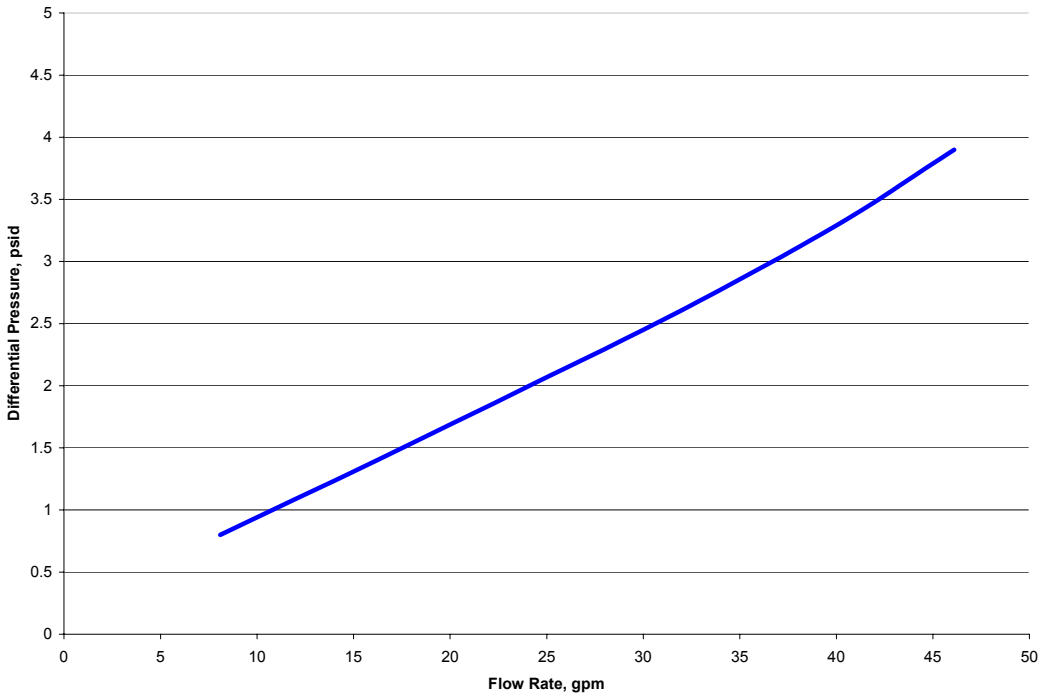

Figure 1. Restriction to Flow Results

These results conformed to the requirements outlined in Section 3.3.1.

Media migration was also determined during this section and conformed to the requirements outlined in Section 3(c). Typical media migration results are shown in Figure 2.

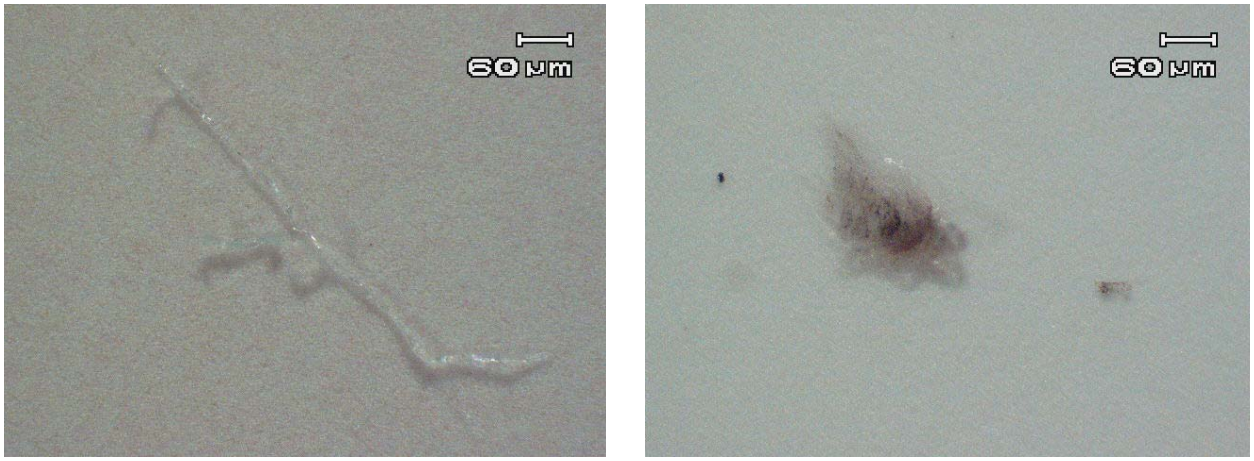

Figure 2. Typical Media Migration Results

5.2 Section 4.4.3.7—Red Iron Oxide

Red iron oxide was continuously injected into the test fuel at a rate of 0.143 grams per gallon of fuel circulated until the differential pressure reached 75 psid. The differential pressure was maintained for a minimum of 5 minutes to determine the structural integrity of the filters. The elements conformed to the requirements outlined in Section 3.3.4.1(b), having a differential pressure of 4.7 psid after 30 minutes and 37.6 psid after 70 minutes. No structural failures were found in the examination of the tested elements.

Photographs of the first set of test elements for tests 1 and 2 are shown in Figures 3 and 4.

Figure 3. First Set of Test Filters—Media Migration and Red Iron Oxide Challenge

Figure 4. Pleated Media for First Set of Test Filters—Media Migration and Red Iron Oxide Challenge

5.3 Section 4.4.3.8—Water Removal (Second Set of Elements)

The water removal tests consisted of two separate 1-hour water challenges: the first hour at 0.5-percent by volume and the second hour at 5.0 percent by volume water challenges. During the last 15 minutes of the second hour, the amount of fuel in the discharge water was checked by

taking a 5-gallon water sample from the filter-separator sump. No fuel was visibly present in the discharge water. NOTE: Aqua-glo was used for determining the amount of free water, as it is the currently accepted method.

The maximum free water value for the first hour was 2-ppm, while the maximum value for the second hour was 8-ppm. The limit per section 3.3.3 is 5-ppm free water. **This nonconformance constitutes a failure.**

5.4 Section 4.4.3.9—Red Iron Oxide and Water

The second set of filters was used for this section, whereby the test elements were challenged with red iron oxide and water. The differential pressure across the media should not exceed 20 psid before 30 minutes nor 40 psid before 70 minutes. At 30 minutes, the differential pressure was 12.4 psid, conforming to section 3.3.4.1(a). However, the differential pressure at 60 minutes was 52.7 psid, exceeding the limits. **This nonconformance constitutes a failure.**

Photographs from the second set of test filters are shown in Figures 5–9.

Figure 5. Second Set of Test Filters—Water and Red Iron Oxide/Water Challenges

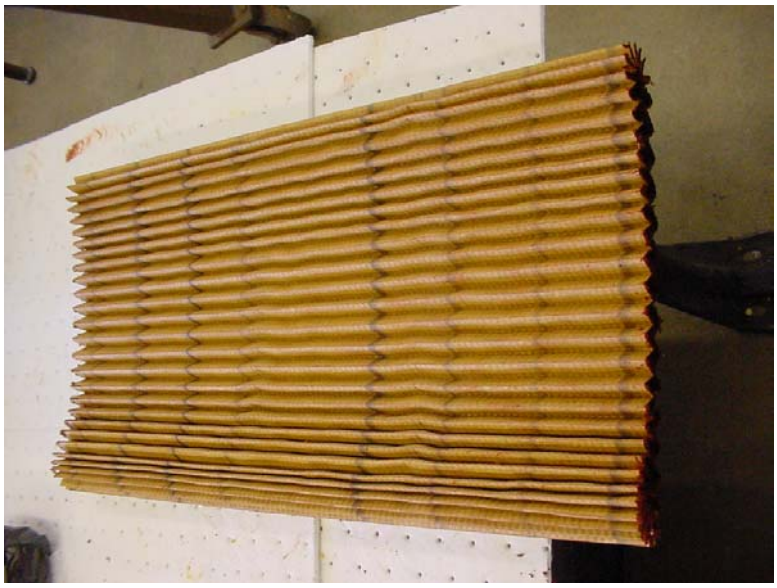

Figure 6. Second Set of Test Elements—Outer Side of Pleated Media: Water and Red Iron Oxide/Water Challenges

Figure 7. Second Set of Test Elements—Inner Side of Pleated Media: Water and Red Iron Oxide/Water Challenges

Figure 8. Second Set of Test Elements—Coalescing Media: Water and Red Iron Oxide/Water Challenges

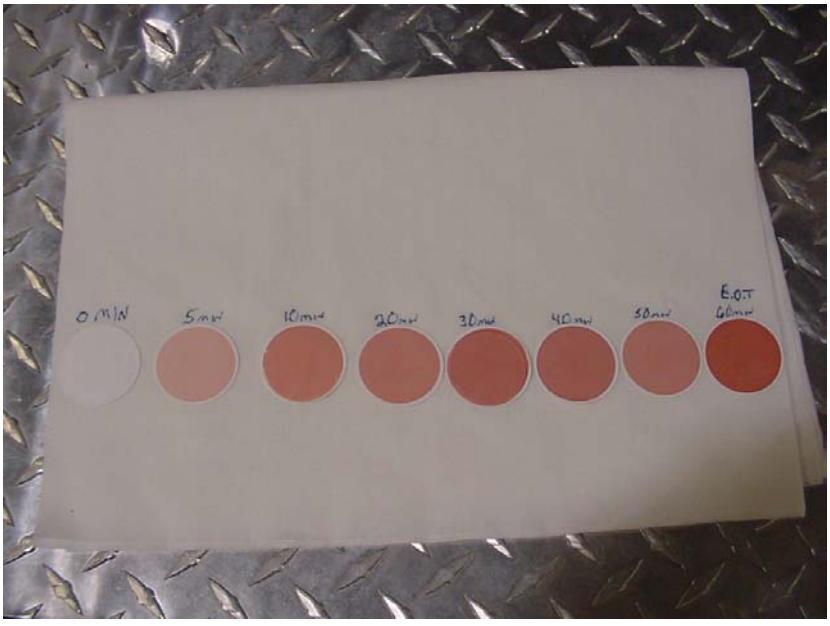

Figure 9. Millipore Membranes From Red Iron Oxide/Water Challenge

5.5 Section 4.4.3.10—Inhibited Fuel (Third Set of Elements)

The inhibited fuel was treated with Stadis 450 (2 mg/L), HiTec E580 (15 ppm), and di-etylene glycol mono-methyl ether (Di-EGME) (0.15%), as described in MIL-F-52308F, section 4.4.2. The differential pressure results conformed to the requirements in section 4.4.3.10 for both portions of the test. The highest differential pressure reading was 13.4 psid.

The solids in the effluent fuel samples did not exceed the 0.5 mg/L limit set forth in section 3.2 (9b). The highest fuel sample solids reading was 0.4 mg/L.

The effluent water content as measured by Aqua-glo exceeded the requirements set forth in section 3.2 (c), as most of the effluent readings were greater than 5 ppm, with many greater than 10 ppm. **This non-conformance constitutes a failure.**

Photos of the third set of elements are shown in Figures 10–12.

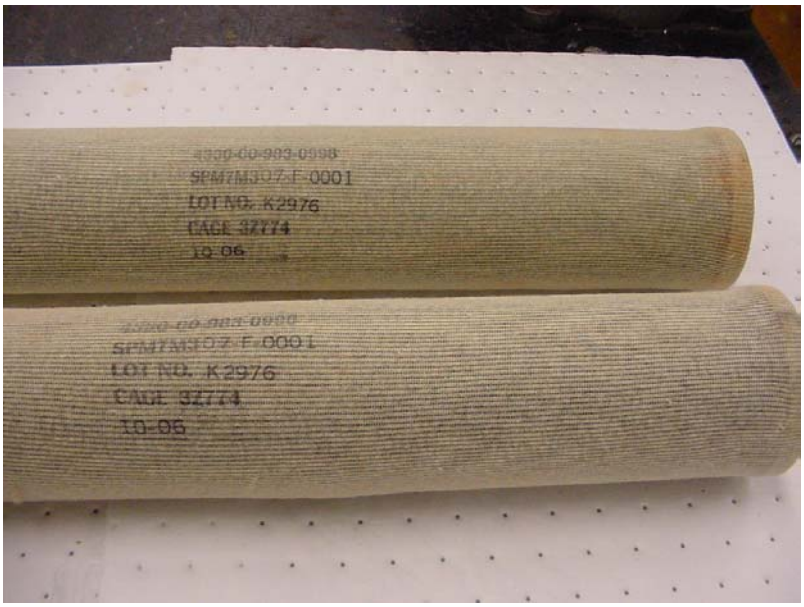

Figure 10. Third Set of Elements—Inhibited Fuel

Figure 11. Third Set of Elements—Particulate Media

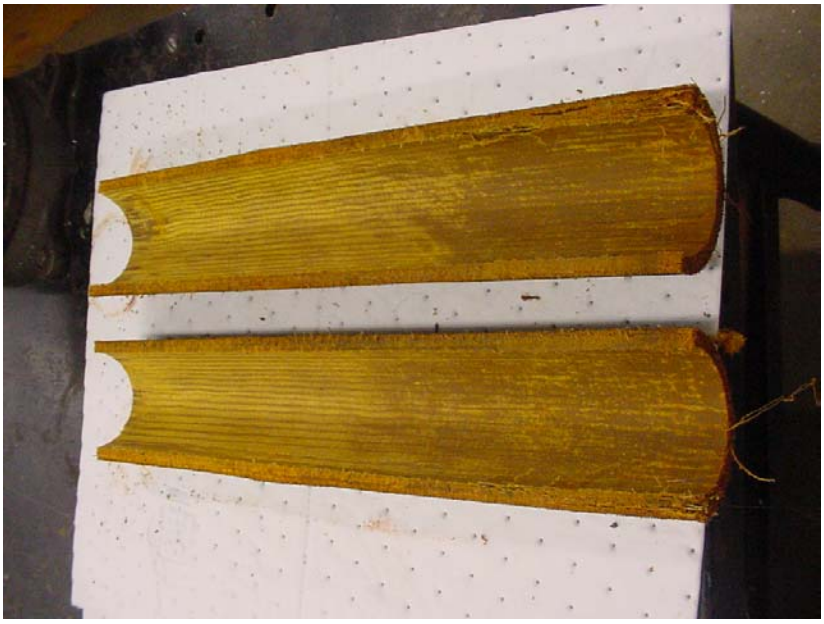

Figure 12. Third Set of Elements—Coalescing Media

5.6 Section 4.4.3.11—Life (Fourth Set of Elements)

The 16-day life test was performed at a flow rate of 40 gpm. The solids and water results conformed to section 3.2 (b) and (c), with the exception of the final hour when the water challenge was increased to 3%. The effluent water contents were greater than 60 ppm. The solid results were still within specification. **This non-conformance constitutes a failure.**

A photo of the fourth set of elements is shown in Figure 13.

Figure 13. Fourth Set of Elements—Life

5.7 Section 4.4.3.12—Environmental

The environmental sections pertaining only to the elements was performed. These evaluations were performed in the following order: high temperature, low temperature, fuel resistance, and salt water. The elements were evaluated between each evaluation with no defects noted. The post environmental performance was performed per section 4.4.3.8, and at 0.5% water per section 4.4.3.17. The elements met the guidelines as determined in section 3.2 (a).

Photos of the elements used in the environmental testing are shown in Figures 14–16.

Figure 14. Test Elements from Environmental Tests

Figure 15. Test Elements from Environmental Tests—Inner Side of Pleated Media

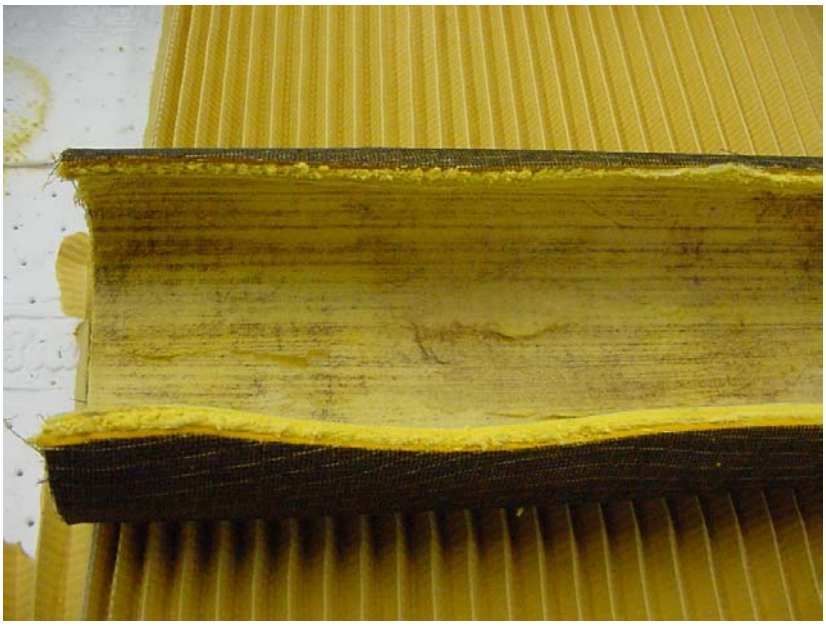

Figure 16. Test Elements from Environmental Tests—Coalescing Media

6.0 CONCLUSIONS

The test elements failed the following sections:

- Section 4.4.3.8—Water removal: This failure is slight as the highest reading was only 8 ppm. Since the water determination used Aqua-glo versus turbidity, variation in the different test methods should be taken into consideration.

- Section 4.4.3.9—Red iron oxide and water: The differential pressure exceeded the upper limits.

- Section 4.4.3.10—Inhibited fuel: This failure occurred both with the water challenge and the dirt/water challenge. The failure was exacerbated with the dirt challenge.

- Section 4.4.3.11—Life test: The water limits were exceeded. The solids were within specifications.

APPENDIX

Test Data Sheet No. 1

Test Paragraph Title: 4.4.3.6 Differential Pressure and Media Migration
Date of Test: 7/10/2007
Test Personnel: Ray Lemes/Gary Bessee
Test Fuel: Jet A MSEP - 99

Time, min	% flow rate	Flow rate, gpm	Pressure, inlet	Differential Pressure, psid	Temperature, F
10	100	40.1	39.4	3.3	81
20	80	31.9	42.1	2.6	81
30	60	24.1	42.9	2	81
40	40	16.2	42.6	1.4	81
50	20	8.1	42.8	0.8	81
60	115	46.1	35.9	3.9	80

Test Data Sheet No. 2

Test Procedure Paragraph Title: 4.4.3.7 Red Iron Oxide
Date of Test: 7/11/2007
Test Personnel: Ray Lemes/Gary Bessee
Test Fuel: Jet A MSEP - 99

Time, min	Flow rate, gpm	Inlet pressure	DP	Temp, F	Gravimetric, mg/L
0	40	38.8	3	88	0
5	40.1	38.8	3.1	88	0
10	39.8	38.7	3.1	88	0.05
20	40.1	39.6	3.8	86	0
30	40.2	40	4.7	85	0
40	40.3	41	7.3	85	0.05
50	40	41.3	11.3	84	0
60	40.2	40.4	22.8	84	0.05
70	40.1	53.1	37.6	84	0
80	39.9	63.3	52.7	84	0.075
85	40.2	90.2	75.9	84	0.075
90	40.3	88.7	75.3	83	0.075

Test Data Sheet No. 3

Test Procedure Paragraph Title: 4.4.3.8 Water Removal Test
Date of Test: 7/16/2007
Test Personnel: Ray Lemes/Gary Bessee
Test Fuel: Jet A MSEP - 99
Water Add Rate - 1st Hour - 0.5%; 2nd Hour - 5%

Time, min	Flow rate, gpm	Inlet pressure	DP	Temp F	Water, ppm
0	46.2	45.5	3.9	84	1
10	45.9	45.6	4.5	84	1
20	46.1	46.4	5.1	83	1
30	46	47	5.7	83	1
40	46	47.6	6.3	83	2
50	46	48.2	6.6	82	2
60	46	48.2	7	82	2
70	46.1	50	8.4	82	4
80	45.9	50.1	8.7	82	6
90	46	49.8	9	82	6
100	46	50.5	9.2	82	6.5
110	46	50.8	9.3	82	6
120	46	50.8	9.5	82	8

Water Surface Tension - 69 mN/m
Water pH - 6.9
Water Discharge Sum Sample - No visible fuel content
Water Solids Content - <0.1 mg/L
Fuel Water Interfacial Tension - 44.5 mN/m
MSEP - 99

Test Data Sheet No. 4

Test Procedure Paragraph Title: 4.4.3.9 Red Iron Oxide and Water Removal Test
Date of Test: 7/19/2007
Test Personnel: Ray Lemes/Gary Bessee
Test Fuel: Jet A MSEP - 99
RIO Injection Rate - 0.143 g/gal
Water Injection Rate - 3.0%

Time, min	Flow rate, gpm	Inlet pressure	DP	Temp, F	Free Water, ppm	Gravimetric, mg/L
0	40.1	39.9	5.2	81	<1	0.1
5	40	41.7	7.3	81	>24	0.4
10	40	42.6	8.3	81	>24	0.8
20	40.6	44.5	10.3	81	>24	0.8
30	40.2	44.7	12.6	78	>24	1.3
40	40	45.8	14.2	78	>24	0.9
50	39.9	48.8	17.6	79	>24	0.5
60	40.1	62	52.7	79	>24	1.2

Water pH - 6.8
Fuel Water Interfacial Tension - 43.6 mN/m

Test Data Sheet No. 5

Test Procedure Paragraph Title: 4.4.3.10 Inhibited Fuel Test
Date of Test: 8/20/2007
Test Personnel: Ray Lemes/Gary Bessee
Test Fuel: JP-8 MSEP - 99/56

Time, min	Flow rate, gpm	Inlet pressure	DP	Temp, F	Gravimetric, mg/L	Water, ppm
1% water injection						
0	40	32.7	3.8	80	0	1
10	39.9	33.1	6.6	80	0.1	6
20	40	34.3	7.6	80	0.1	10
30	40	35.2	8.2	80	0	10
40	40.1	36	8.7	80	0.2	11
50	40.2	36.4	9	80	0.1	32
60	39.9	36.3	9.2	80	0.1	20
1% water and A2 test dust						
70	40.1	37.2	9.6	80	0.1	28
80	39.8	37.7	10.8	80	0.4	24
90	40.1	36.9	11.1	80	0	44
100	40.2	36.2	12.2	80	0	24
110	40.1	36.1	12.5	80	0.3	50
120	40	36.7	13	80	0.3	40
130	39.9	37.2	13.4	80	0.1	50

MSEP Before Additives - 99
MSEP After Additives - 56
IFT Before Addtives - 43.69 mN/m
IFT After Additives - 41.81 mN/m

Test Data Sheet No. 6

Test Procedure Paragraph Tests: 4.4.3.11
Date of Test: 7/23/2007 through 8/13/2007
Test Personnel: Ray Lemes/Gary Bessee
Test Fuel: Jet A MSEP - 99

Time, minutes	Flow Rate, gpm	Inlet pressure	DP	Temp, F	Gravimetric, mg/L	Water, ppm
Day 1						
0	40.1	24.1	3.4	78	0.2	<1
15	39.9	28.6	8	78	0.3	1
30	40	31.3	10.5	77	0.2	<1
45	40.1	30.7	9.9	76	0.3	<1
60	40.1	30.8	9.9	76	0.1	<1
75	39.8	30.9	10.5	75		
90	39.8	30.9	10.4	75		
105	40	30.8	10.1	74		
120	40.4	30.8	9.8	74		
135	40.6	30.6	9.5	74		
150	40.1	30.8	10	74		
165	40.6	30.6	9.4	74		
180	39.8	30.9	10.4	74		
195	39.9	30.9	10.2	74		
210	40.1	30.8	10.1	74		
225	40.1	30.9	9.9	74		
240	40.1	30.8	10	74		
255	40.1	30.8	10	75		
270	40.2	30.8	10	75		
285	40.3	30.7	9.8	75		
300	39.9	30.8	10.1	75		
315	40	30.8	10.1	75		
330	40	30.8	9.9	75		
345	40.1	30.8	9.9	75		
360	39.9	30.9	10.2	75		
375	39.8	30.8	10.2	75		
390	40	31.8	10.4	75		
405	39.9	31.8	10.4	75		
420	40	31.8	10.3	75		
435	40	31.7	10.3	75		
450	40.2	31.7	10.3	75		
465	40.2	30.8	10.1	75		
480	40.1	30.7	10	75	0.2	1

Test Data Sheet No. 6 (continued)

Time, minutes	Flow Rate, gpm	Inlet pressure	DP	Temp, F	Gravimetric, mg/L	Water, ppm
Day 2						
481	39.9	28.3	7.7	74	0	1
495	40	33	12.4	74	0.2	1.5
510	39.8	33.2	12.7	74	0.1	1
525	39.6	33.4	13.2	74	0	1
540	39.7	34	13.7	74	0	1
555	40.1	32.8	11.9	75		
570	39.8	32.3	11.6	75		
585	40	32.3	11.5	75		
600	39.8	32.3	11.5	74		
615	39.9	32.3	11.6	73		
630	39.9	33.2	11.9	73		
645	40.1	33.3	11.9	73		
660	40	32.3	11.6	72		
675	39.9	32.1	11.4	72		
690	39.8	32.8	11.6	72		
705	39.9	32.8	11.4	72		
720	39.8	32.6	11.2	72		
735	39.9	32.3	11.1	72		
750	40	32.1	10.8	72		
765	39.8	31.1	10.4	72		
780	39.9	31.1	10.3	72		
795	40	31.1	10.2	72		
810	40	31.1	10.2	72		
825	40.1	31	10.1	72		
840	40.2	31	10.1	72		
855	40.1	31.7	10.2	72		
870	40	30.8	9.9	72		
885	40.1	30.8	9.9	72		
900	40.1	30.7	9.9	72		
915	40	31.3	10	72		
930	40	31.3	10	73		
945	40	31.2	9.9	73		
960	40.1	31.3	9.9	73	0	1

Test Data Sheet No. 6 (continued)

Time, minutes	Flow Rate, gpm	Inlet pressure	DP	Temp, F	Gravimetric, mg/L	Water, ppm
Day 3						
961	40	28.2	7.4	73	0	<1
975	39.8	30.8	10.2	73	0.1	1.5
990	39.9	31.7	11.1	73	0.2	1
1005	39.4	32.5	11.8	72	0.2	1
1020	40.2	33	10.8	80	0.2	1
1035	40.2	31.8	9.7	81		
1050	39.8	31.9	10	81		
1065	40.2	32	9.9	81		
1080	39.8	32.1	10.2	81		
1095	39.8	32.2	10.2	80		
1110	39.9	32.1	10.1	78		
1125	40.1	32.1	9.9	78		
1140	40.2	32	9.8	77		
1155	40	32.1	10.2	77		
1170	40.1	32.2	10.1	76		
1185	40	32.1	10	75		
1200	40.1	32.1	9.9	75		
1215	40.2	32.1	9.9	75		
1230	40.2	32	9.9	75		
1245	39.9	32.2	10.2	75		
1260	39.8	32.2	10.2	75		
1275	39.8	32.2	10.2	75		
1290	40	32.2	10.1	75		
1305	40	32.2	10.1	75		
1320	40	32.1	10.1	75		
1335	40	32.1	10.1	75		
1350	40	32.2	10.1	75		
1365	40.1	32.2	10.1	75		
1380	40	32.2	10.1	76		
1395	40	32.1	10.1	76		
1410	40.1	32.1	10.1	76		
1425	40	32.2	10.1	76		
1440	40	32.2	10.1	76	0.2	<1

Test Data Sheet No. 6 (continued)

Time, minutes	Flow Rate, gpm	Inlet pressure	DP	Temp, F	Gravimetric, mg/L	Water, ppm
Day 4						
1441	39.9	33	7.5	79	0	<1
1455	40	34.3	10.6	79	0.2	1.5
1470	39.9	34.9	11.3	79	0	1
1485	39.8	35.5	12.1	80	0.1	1
1500	39.9	35.8	12.2	79	0.2	1
1515	40.1	34.4	10.7	79		
1530	40	34	10.2	78		
1545	40	33.7	10	77		
1560	39.9	33.4	9.8	77		
1575	39.6	33.9	10.5	76		
1590	39.7	33.8	10.5	76		
1605	39.6	33.7	10.3	76		
1620	40	33.7	10.1	75		
1635	39.8	33.7	10.1	75		
1650	39.9	33.7	10	75		
1665	40.2	34	10	75		
1680	39.9	33.7	10.2	75		
1695	39.8	33.7	10.2	75		
1710	39.8	33.7	10.1	75		
1725	39.9	33.7	10.1	75		
1740	39.8	33.7	10.1	75		
1755	39.8	33.7	10.1	75		
1770	39.8	33.7	10.1	76		
1785	39.8	33.7	10.1	76		
1800	39.8	33.7	10.1	76		
1815	39.8	33.7	10.1	76		
1830	39.8	33.7	10.1	76		
1845	39.8	33.7	10.1	76		
1860	39.8	33.7	10.1	76		
1875	39.8	33.7	10.1	76		
1890	39.8	33.7	10.1	76		
1905	39.8	33.7	10.1	76		
1920	39.8	33.7	10.1	76	0	<1

Test Data Sheet No. 6 (continued)

Time, minutes	Flow Rate, gpm	Inlet pressure	DP	Temp, F	Gravimetric, mg/L	Water, ppm
Day 5						
1921	40.3	33.1	8	82	0.1	1
1935	39.8	35.5	10.8	79	0.3	2
1950	39.8	36.1	11.6	79	0.2	1
1965	39.8	37	12.3	78	0.2	1
1980	39.8	37.6	12.9	78	0.1	<1
1995	40.1	35.9	11	76		
2010	39.9	35.5	10.8	76		
2025	40	35.5	10.6	75		
2040	40	34.9	10.3	75		
2055	40.1	34.9	9.9	75		
2070	40.1	34.5	9.7	75		
2085	39.8	34.7	9.9	75		
2100	40.2	34.8	9.8	75		
2115	39.8	34.9	10.4	75		
2130	40	34.9	10.2	75		
2145	40	34.9	10.1	75		
2160	40	34.9	10.1	75		
2175	40	34.9	10.1	75		
2190	40.1	34.9	10.1	75		
2205	40	34.9	10.1	75		
2220	40	34.9	10.1	75		
2235	40.1	34.9	10.1	75		
2250	40.1	34.9	10.1	75		
2265	40.1	34.9	10.1	75		
2280	40	34.9	10.1	75		
2295	40	34.9	10.1	75		
2310	40	34.9	10.1	75		
2325	40	34.9	10.1	75		
2340	40	34.9	10.1	75		
2355	40	34.9	10.1	75		
2370	40	34.9	10.1	75		
2385	40	34.9	10.1	75		
2400	40	34.9	10.1	75	0.2	<1

Test Data Sheet No. 6 (continued)

Time, minutes	Flow Rate, gpm	Inlet pressure	DP	Temp, F	Gravimetric, mg/L	Water, ppm
Day 6						
2401	40.2	32.5	7.7	81	0	<1
2415	39.6	35.3	11	77	0.2	1.5
2430	40	36.5	11.7	77	0.1	1
2445	39.8	37.1	12.4	77	0	1
2460	39.9	37.8	13	76	0.2	<1
2475	40	35.9	11.3	76	0.1	<1
2490	40	35.5	10.8	75		
2505	40	35.2	10.5	74		
2520	40.1	34.9	10.1	74		
2535	40.1	34.6	9.9	74		
2550	40.2	34.6	9.7	73		
2565	39.7	34.8	10.5	73		
2580	39.8	34.8	10.4	73		
2595	39.8	34.7	10.2	73		
2610	40	34.9	10.2	73		
2625	40.1	34.9	10.1	73		
2640	40	34.9	10.1	73		
2655	40	34.9	10.1	74		
2670	40.1	34.9	10.1	74		
2685	40.2	34.9	10	74		
2700	40.2	34.9	10	74		
2715	40.2	34.9	10	74		
2730	40	35	10.2	74		
2745	40	34.9	10.2	74		
2760	40	34.9	10.2	74		
2775	40.1	34.9	10.2	75		
2790	40	34.9	10.2	75		
2805	39.9	34.9	10.2	75		
2820	40	34.9	10.2	75		
2835	40.1	34.9	10.2	75		
2850	40	34.9	10.2	75		
2865	40	34.9	10.1	75		
2880	40	34.9	10.2	75	0.3	<1

Test Data Sheet No. 6 (continued)

Time, minutes	Flow Rate, gpm	Inlet pressure	DP	Temp, F	Gravimetric, mg/L	Water, ppm
Day 7						
2881	40	32.6	7.8	80	0.1	<1
2895	39.9	36	11.2	77	0.1	1.5
2910	39.7	36.2	11.7	77	0	1
2925	39.8	36.8	12.2	77	0.3	1
2940	40	37.6	12.9	77	0	<1
2955	40.2	36.4	11.4	76		
2970	40.1	35.6	10.8	75		
2985	40.2	35.5	10.5	75		
3000	40.2	35.2	10.1	75		
3015	40.3	34.8	9.8	75		
3030	39.8	35	10.5	75		
3045	40	34.9	10.3	75		
3060	39.9	34.9	10.2	75		
3075	40	34.9	10.1	75		
3090	40.2	34.9	10.1	75		
3105	40.2	34.9	10	75		
3120	40	34.9	9.9	75		
3135	40.1	34.9	10	75		
3150	40.1	34.8	10	75		
3165	40	34.9	9.9	75		
3180	40.1	34.9	9.9	75		
3195	40.1	34.9	9.9	75		
3210	40.1	34.9	9.9	75		
3225	40.1	34.9	9.9	75		
3240	40	34.9	9.9	76		
3255	40	34.9	9.9	76		
3270	40.1	34.9	9.9	76		
3285	40	34.9	9.9	76		
3300	40	34.9	9.9	76		
3315	40.1	34.9	9.9	76		
3330	40.1	34.9	9.9	76		
3345	40	34.9	9.9	76		
3360	40	34.8	9.9	76	0	<1

Test Data Sheet No. 6 (continued)

Time, minutes	Flow Rate, gpm	Inlet pressure	DP	Temp, F	Gravimetric, mg/L	Water, ppm
Day 8						
3361	40.1	34.9	7.8	79	0	<1
3375	39.8	35.7	11.1	77	0	2
3390	40	36.5	11.8	77	0	1.5
3405	39.9	37.1	12.5	77	0.2	1
3420	39.8	37.7	13	76	0.2	1
3435	40.1	36.1	11.3	75		
3450	40	35.7	10.9	75		
3465	40	35.2	10.5	74		
3480	40	34.9	10.2	74		
3495	40.2	34.9	9.9	74		
3510	40.2	35	10.2	74		
3525	40.2	35	10.1	74		
3540	40.3	34.9	10	74		
3555	40.2	34.6	9.9	74		
3570	39.8	34.8	10.4	74		
3585	39.9	34.7	10.4	74		
3600	39.8	34.7	10.3	74		
3615	39.8	34.7	10.3	74		
3630	39.8	34.7	10.2	74		
3645	39.8	34.7	10.2	74		
3660	39.8	34.7	10.1	74		
3675	39.8	34.7	10.1	74		
3690	39.9	34.7	10.2	75		
3705	39.8	34.7	10.1	75		
3720	39.8	34.7	10.1	75		
3735	39.8	34.7	10.1	75		
3750	40	34.7	10.1	75		
3765	40	34.6	10.1	75		
3780	39.8	34.7	10.1	75		
3795	39.9	34.7	10.1	75		
3810	39.8	34.6	10.1	75		
3825	39.9	34.6	10.1	75		
3840	39.9	34.7	10.1	75	0	<1

Test Data Sheet No. 6 (continued)

Time, minutes	Flow Rate, gpm	Inlet pressure	DP	Temp, F	Gravimetric, mg/L	Water, ppm
Day 9						
3841	40.2	34.5	7.8	79	0.2	<1
3855	40	35.7	11.2	78	0	1.5
3870	40	36.5	11.9	78	0	1
3885	40	37.2	12.6	78	0.1	1
3900	40	37.6	13	77	0.2	<1
3915	40.2	37.6	12.1	76		
3930	40	37.6	10.7	75		
3945	40.1	37.5	10.3	75		
3960	40.2	36.8	9.8	75		
3975	40.1	36.9	9.9	74		
3990	40.1	36.8	9.9	74		
4005	40	36.8	10.2	74		
4020	40.1	36.9	10.1	74		
4035	40	36.8	10	74		
4050	40.1	36.8	9.9	74		
4065	40.1	368	9.9	75		
4080	40.2	36.8	9.9	75		
4095	40.2	37.7	9.9	75		
4110	40.1	36.8	10.1	75		
4125	40	36.8	10.1	75		
4140	40	36.8	10.1	75		
4155	40.1	36.8	10.1	75		
4170	40	36.8	10.1	75		
4185	40	36.8	10	75		
4200	40.1	36.8	10	75		
4215	40	36.8	10.1	75		
4230	40	36.8	10	76		
4245	40.2	36.7	10	76		
4260	40.2	36.8	10	76		
4275	40	36.7	9.9	76		
4290	40.2	36.7	9.9	76		
4305	40.2	36.7	9.9	76		
4320	40.2	36.7	9.9	76	0.1	<1

Test Data Sheet No. 6 (continued)

Time, minutes	Flow Rate, gpm	Inlet pressure	DP	Temp, F	Gravimetric, mg/L	Water, ppm
Day 10						
4321	40.2	36.7	7.7	79	0.2	<1
4335	40.1	38.1	11.3	79	0.1	1
4350	40	38.8	12.1	79	0	1
4365	40	39.5	12.7	78	0.1	1
4380	40	39.8	13.2	78	0.1	1
4395	39.8	40.4	11.4	77		
4410	40	40.1	10.8	76		
4425	40	39.5	10.5	75		
4440	40	39.1	10.1	75		
4455	40.1	38.9	9.8	74		
4470	40	39.1	10.2	74		
4485	39.8	39	10.1	74		
4500	40	39	9.9	74		
4515	40.1	39.1	9.9	74		
4530	40	38.9	9.9	74		
4545	40.1	38.9	9.9	74		
4560	40	39	9.9	74		
4575	40.1	39	9.8	75		
4590	40.1	39.2	10.1	75		
4605	40.2	39.2	10.1	75		
4620	40.2	39.2	10.1	75		
4635	40.2	39.2	10.1	75		
4650	40.2	39.2	10.1	75		
4665	40.2	39.1	10	75		
4680	40.2	39.1	10	75		
4695	40.2	39.2	9.9	75		
4710	40.2	39.1	9.9	75		
4725	40.2	39.1	10	75		
4740	40.2	39.1	10	75		
4755	40.2	39.1	9.9	76		
4770	40.1	39.1	9.9	76		
4785	40.2	39.2	9.9	76		
4800	40.2	39.1	9.9	76	0.2	<1

Test Data Sheet No. 6 (continued)

Time, minutes	Flow Rate, gpm	Inlet pressure	DP	Temp, F	Gravimetric, mg/L	Water, ppm
Day 11						
4801	40.2	39.1	7.7	80	0	<1
4815	40	39.5	11	80	0.1	1.5
4830	40.1	39.4	11.8	80	0	1
4845	40.2	39.4	12.6	79	0	1
4860	39.8	39.5	13.2	78	0	<1
4875	40.1	37.9	11.1	77		
4890	40.2	37.6	10.8	76		
4905	40	36.8	10.3	76		
4920	40	36.5	9.9	75		
4935	40.3	36.5	9.7	74		
4950	40.1	36.5	10	74		
4965	40.1	36.7	10	74		
4980	39.9	36.9	10.1	74		
4995	40	36.9	10.1	74		
5010	40	36.8	10.1	74		
5025	40	36.8	10.1	74		
5040	40	36.8	10	74		
5055	40	36.8	10	74		
5070	40	36.8	10	74		
5085	40.2	36.7	9.9	75		
5100	40	36.7	10	75		
5115	40	36.7	10	75		
5130	40.1	36.8	10	75		
5145	40.1	36.7	10	75		
5160	40.2	36.7	10	75		
5175	40.2	36.8	10	75		
5190	40.2	36.7	9.9	75		
5205	40.2	36.7	9.9	75		
5220	40.1	36.7	9.9	76		
5235	40.2	36.7	9.9	76		
5250	40.1	36.8	9.9	76		
5265	40.2	36.7	9.9	76		
5280	40	36.7	9.9	76	0	<1

Test Data Sheet No. 6 (continued)

Time, minutes	Flow Rate, gpm	Inlet pressure	DP	Temp, F	Gravimetric, mg/L	Water, ppm
Day 12						
5281	39.9	36.7	7.7	80	0	<1
5295	40	37.9	11.1	80	0	2
5310	39.8	38.7	12.2	79	0	1.5
5325	39.8	39.4	13	78	0	1
5340	40	40.1	13.3	78	0.2	1
5355	39.8	40.1	11.3	77		
5370	40	39.5	10.5	75		
5385	40	39.5	10.5	75		
5400	40.2	39.2	10.1	74		
5415	40.1	39	9.9	74		
5430	40	39.1	10.2	74		
5445	40	39	10.1	74		
5460	40.1	38.9	10	74		
5475	40.1	38.9	9.9	74		
5490	40.1	38.9	9.9	74		
5505	40.1	39.1	9.9	74		
5520	40	38.9	9.9	74		
5535	39.9	39.1	10.1	74		
5550	40	39	10.1	74		
5565	40	39.1	10.1	74		
5580	40	39	10.1	74		
5595	40	39	10.1	74		
5610	40	39	10.1	75		
5625	40	39	10.1	75		
5640	40	39	10.1	75		
5655	40	39	10.1	75		
5670	40	39	10	75		
5685	40	39	10.1	75		
5700	40	38.9	10	75		
5715	40	39	10	75		
5730	40	39	9.9	75		
5745	39	38.9	9.9	76		
5760	40	38.9	9.9	76	0.2	<1

Test Data Sheet No. 6 (continued)

Time, minutes	Flow Rate, gpm	Inlet pressure	DP	Temp, F	Gravimetric, mg/L	Water, ppm
Day 13						
5761	40.1	38.9	7.7	80	0	<1
5775	40	40.4	11.6	79	0	1.5
5790	40	40.9	12.2	79	0	1
5805	39.9	41.7	13	79	0.1	1
5820	40	42.5	13.4	78	0	1
5835	39.8	42.8	11.6	77		
5850	40.1	42.6	11	76		
5865	40.1	41.9	10.3	75		
5880	40.2	41.7	10.1	75		
5895	40.2	41.5	9.9	74		
5910	40.1	41.6	9.9	74		
5925	40.2	41.4	9.8	74		
5940	40.1	41.6	9.9	74		
5955	40.1	41.6	9.9	74		
5970	40	41.6	9.9	74		
5985	40.2	41.6	9.9	74		
6000	40	41.6	10	74		
6015	39.8	41.6	9.9	74		
6030	40	41.5	9.9	74		
6045	40.1	41.4	9.9	74		
6060	40	41.6	9.9	74		
6075	40	41.5	9.9	74		
6090	40	41.5	9.9	75		
6105	40.1	41.6	9.9	75		
6120	40.1	41.5	9.9	75		
6135	40	41.4	9.9	75		
6150	40.1	41.5	9.9	75		
6165	40	41.4	9.9	75		
6180	39.9	41.4	9.9	75		
6195	40.2	41.5	9.9	75		
6210	40	41.5	9.9	76		
6225	40.1	41.4	9.9	76		
6240	40.1	41.4	9.9	76	0	<1

Test Data Sheet No. 6 (continued)

Time, minutes	Flow Rate, gpm	Inlet pressure	DP	Temp, F	Gravimetric, mg/L	Water, ppm
Day 14						
6241	40	41.5	7.7	80	0.1	1
6255	39.9	42.6	11.2	80	0	1.5
6270	39.8	43.5	12.4	81	0	1
6285	40	44	12.7	80	0	1
6300	39.8	44.2	12.9	80	0.1	1
6315	40	44.9	10.7	80		
6330	40	44	9.9	80		
6345	40.1	44.3	9.9	80		
6360	40.1	44.2	9.8	80		
6375	40	44.3	10	79		
6390	40.2	44.3	10	79		
6405	40	44.3	9.9	79		
6420	40	44.3	9.9	78		
6435	40	44.3	9.9	78		
6450	40	44.3	9.9	78		
6465	40	44.3	939	78		
6480	39.9	44.3	9.9	78		
6495	40	44.3	9.9	77		
6510	40	44.3	10	77		
6525	40	44.3	10	77		
6540	40	44.3	10	77		
6555	40	44.3	10	77		
6570	40	44.3	10	77		
6585	40	44.3	10.1	77		
6600	40	44.3	10.1	77		
6615	40	44.4	10.1	77		
6630	40	44.3	10.1	77		
6645	40.1	44.3	10	77		
6660	40	44.3	10	77		
6675	40	44.3	10.1	77		
6690	40	44.3	10.1	77		
6705	40.1	44.3	10.1	77		
6720	40	44.4	10.1	77	0.1	<1

Test Data Sheet No. 6 (continued)

Time, minutes	Flow Rate, gpm	Inlet pressure	DP	Temp, F	Gravimetric, mg/L	Water, ppm
Day 15						
6721	40	42.5	8.1	83	0	<1
6735	39.9	41.1	11.7	79	0	2
6750	40	47	12.6	79	0	1
6765	40.1	47.8	13.4	79	0.1	<1
6780	39.9	48.2	13.9	79	0.1	<1
6795	40	46.1	11.7	78		
6810	40	45.8	11.2	77		
6825	40	44.9	10.5	77		
6840	39.9	44.3	10.1	76		
6855	40	44.3	9.8	76		
6870	40	44.2	10	76		
6885	40	44.3	9.9	76		
6900	40.1	44.3	9.8	76		
6915	40	44.4	10.1	76		
6930	39.9	44.4	10.1	76		
6945	40	44.3	10.1	76		
6960	40	44.3	10	76		
6975	40.1	44.4	10	76		
6990	40	44.1	9.9	76		
7005	40	43.9	9.9	77		
7020	39.9	44	9.9	77		
7035	40.1	44.1	9.9	77		
7050	40.2	44	9.9	77		
7065	40.1	44.1	9.9	77		
7080	40.1	44.1	9.9	77		
7095	40	44.1	9.9	77		
7110	40	44	9.9	77		
7125	40.2	44.1	9.9	77		
7140	40.2	44.1	9.9	77		
7155	40	44.1	9.9	77		
7170	40.1	44.1	9.9	77		
7185	40	44	9.9	77		
7200	40.1	44	9.9	77	0	<1

Test Data Sheet No. 6 (continued)

Time, minutes	Flow Rate, gpm	Inlet pressure	DP	Temp, F	Gravimetric, mg/L	Water, ppm
Day 16						
7201	39.8	44.9	7.9	80	0	<1
7215	39.8	45.7	11.9	80	0	1.5
7230	39.8	46.5	12.8	79	0.1	1
7245	39.8	47.4	13.5	79	0.1	1
7260	39.8	48.3	14.2	78		
7275	40.1	46.2	11.9	77		
7290	40	45.6	11.4	77		
7305	39.9	45	10.8	76		
7320	40	44.7	10.3	76		
7335	40.1	44.4	10.1	75		
7350	40.1	44.1	9.8	75		
7365	40	44.4	10	75		
7380	40	44.4	10.1	75		
7395	40.1	44.2	10	75		
7410	40	44.1	10	75		
7425	39.8	44	10.1	75		
7440	40	44.1	10	75		<1
7455	40.2	44.1	22.5	75		>24
7470	40.1	46.2	24.7	76		>24
7485	40	46.8	26.6	76		>24
7500	39.9	46.8	27.9	77	0.3	>24